We claim:

1. An optical device comprising at least two waveguides in at least one propagation layer of grating material, a first one of said waveguides adapted for transporting input radiation from a first input port to output radiation exiting from a first output port and a second one of said waveguides transporting input radiation from a second input port to output radiation exiting from a second output port, and a one- or two- dimensional (binary) supergrating in a modulation layer of grating material for coupling input radiation propagating from one of said first and second input ports along a corresponding waveguide to the other of said first and second waveguides

2. A device according to claim 1, in which said one- or two- dimensional supergrating couples input radiation in said first waveguide traveling in a first direction to said second waveguide traveling in a second direction substantially parallel to said first direction.

3. A device according to claim 1, in which said one- or two- dimensional supergrating couples input radiation in said first waveguide travelling in a first direction to said second waveguide, traveling in a second direction substantially opposite to said first direction.

4. A device according to claim 1, in which said first and second waveguides are symmetric and said one- or two-dimensional supergrating comprises a central portion between said first and second waveguides having a first pattern of high and low values of index of refraction and

first and second outer portions having a second pattern of high and low values of index of refraction having the opposite sense to said first pattern, whereby said one- or two- dimensional supergrating suppresses back reflection in said first and second waveguides.

5. A device according to claim 1, in which said two dimensional supergrating comprises an array of controllable means, responsive to a set of control signals, for altering the modal index of refraction value in corresponding pixels in said array in at least two modes including a first mode in which said device couples input radiation in said first waveguide travelling in a first direction to said second waveguide traveling in a second direction substantially parallel to said first direction and a second mode in which said device couples input radiation in said first waveguide travelling in a first direction to said second waveguide traveling in a second direction substantially opposite to said first direction.

6. A device according to claim 5, in which said one- or two- dimensional supergrating comprises an array of controllable means responsive to a set of control signals that are adapted to switch radiation of any of N different wavelengths between said first and second waveguides in said first and second modes in response to corresponding values of said control signal, whereby said device may be controlled to pass radiation in any one of N wavelengths from any of said input ports to any of said output ports, thereby forming a wavelength-dependent supergrating 2x2 coupler.

7. A device according to claim 1, in which said one- or two- dimensional supergrating comprises an array of controllable means, responsive to a set of control signals, for altering the index of refraction value in corresponding pixels in said array in at least two modes including a first mode in which said device couples input radiation in said first waveguide to said second waveguide and a second mode in which said device couples input radiation in said second waveguide to said first waveguide.

8. A device according to claim 7, in which said one- or two- dimensional supergrating comprises an array of controllable means responsive to a set of control signals that are adapted to switch radiation of any of N different wavelengths between said first and second waveguides in said first and second modes in response to corresponding values of said control signal, whereby said device may be controlled to pass radiation in any one of N wavelengths from any of said input ports to any of said output ports, thereby forming a wavelength-dependent supergrating 2x2 coupler.

9. An NxM system for controllably directing radiation of a selected wavelength from any one of N input ports to any one of M output ports comprising a set of wavelength dependent supergrating couplers arranged to accept incoming radiation in an input wavelength range and to couple radiation entering in any of said N input ports to any of said M output ports, comprising a first row of N/2 input couplers, a final row of M/2 couplers and a set of intermediate mixing couplers that couple radiation from one or more couplers in a preceding row to one or more couplers in the next row.

10. A device according to claim 9, in which said one- or two- dimensional supergrating comprises an array of controllable means responsive to a set of control signals that are adapted to switch radiation of any of N different wavelengths between said first and second waveguides in response to corresponding values of said control signal, whereby said device may be controlled to pass radiation in any one of N wavelengths from any of said input ports to any of said output ports, thereby forming a wavelength-dependent supergrating cross-bar coupler.

11. A device for receiving optical radiation of N input wavelengths and dividing it into N physically separate channels, comprising:
an input channel, a set of wavelength dependent supergrating couplers connected in series to said input channel, each of said set of couplers being adapted to couple radiation in a radiation band from said input channel to an output channel.

12.A device according to claim 11, in which each of said couplers processes a single one of said N channels of radiation.

13. A device according to claim 11, in which at least some of said couplers process a range of channels of radiation and following couplers complete the process of separating each of said N channels.

14. A device for receiving optical radiation of N input wavelengths and dividing it into N physically separate channels, comprising:

an input channel, a two dimensional wavelength dependent supergrating adapted for deflecting radiation of different wavelengths and directing the deflected radiation toward a set of output channels.

15. A device according to claim 14, in which the one- or two- dimensional wavelength dependent supergrating deflects radiation away from the input direction of travel at angles that depend on the wavelength and focus that radiation into a set of waveguides for each wavelength channel.

16. A device for processing optical radiation in a set of wavelengths comprising a set of waveguides having at least one input port and at least one output port, in which an input beam of radiation traveling on an input waveguide passes through at least one wavelength dependent supergrating coupler that couples a selected wavelength band in or out of the input waveguide, so that the remaining optical beam in the input waveguide has a wavelength range that has been added to or subtracted from by the selected wavelength band.

17. A device according to claim 16, in which said wavelength dependent supergrating coupler adds radiation from a second input port to said input beam.

18. A device according to claim 16, in which said wavelength dependent supergrating coupler subtracts radiation in a wavelength subtraction range from said input beam.

19. A device according to claim 16, in which at least two supergrating couplers are connected in series, with a

first supergrating coupler controlling a first wavelength range and a second supergrating coupler controlling a second wavelength range.

20. A device for monitoring the strength of radiation in a waveguide comprising:

An input waveguide containing radiation in a selected wavelength range; and
A wavelength dependent supergrating coupler intercepting said radiation and deflecting a portion of said radiation out of said waveguide and onto a radiation meter responsive to the power of radiation impinging thereon, whereby the magnitude of deflected radiation is a measure of the magnitude of radiation traveling in the waveguide.

21. An optical device for altering the incoming power spectrum of an incoming beam and converting said incoming beam to an outgoing beam having an outgoing power spectrum comprising:
A set of N controllable wavelength sensitive power removal modules for removing a controllable amount of power in a wavelength range from said incoming beam, whereby said incoming power spectrum is converted to said outgoing power spectrum by subtracting power from selected wavelength ranges.

22. An optical amplifier comprising a gain medium for receiving an input beam having an input power spectrum and increasing the energy thereof, thereby forming an output beam having an output power spectrum:
Comprising a power control unit for removing a controllable amount of power in at least one wavelength range from said incoming beam, whereby said input power

spectrum may be adjusted such that said output power spectrum has a desired profile.

23. An array of waveguides arranged in a grid comprising a set of input waveguides for receiving multiplexed inputs comprising at least one wavelength crossing a set of output waveguides, each of the input waveguides having a series of wavelength dependent supergrating couplers that each couple radiation of a selected output wavelength range to a corresponding output waveguide, whereby radiation entering with a number of wavelengths on input waveguides is sorted into a set of output waveguides, each carrying an output wavelength range.

24. A device according to claim 23, in which at least some of said output wavelength ranges cover a single wavelength channel.

25. An optical device for receiving an input beam having an input wavelength dependent group delay spectrum and applying a compensating group delay spectrum, thereby generating an output beam, comprising:

An input port for receiving said input beam;
at least one wavelength dependent supergrating for imposing a compensating wavelength dependent delay on radiation traveling therethrough; and
an output port.

26. A device according to claim 25, in which said input port is connected to an optical circulator that couples input radiation to a reflective supergrating that reflects back radiation into said circulator with said wavelength dependent delay impressed thereon.

27. A device according to claim 25, in which said input port is a first end of a first waveguide having a transmissive supergrating that passes radiation therethrough out a second end of said first waveguide with said wavelength dependent delay impressed thereon.

28. A device according to claim 25, in which said input port is connected to a reflective supergrating that couples input radiation in said first waveguide travelling in a first direction to a second waveguide and traveling in a second direction substantially opposite to said first direction with said wavelength dependent delay impressed thereon.

29. A device according to claim 25, in which said input port is connected to a transmissive supergrating that couples input radiation in said first waveguide traveling in a first direction to a second waveguide traveling in a second direction substantially parallel to said first direction with said wavelength dependent delay impressed thereon.

30. An optical device comprising an input port for receiving incident radiation and directing the radiation on an array of pixels comprising a supergrating, each pixel having a modal index of refraction selected from a set of index values, the array of pixels collectively processing the incident radiation and directing at least one beam of output radiation to at least one output port, in which at least some of the array of pixels are connected to control means for controllably setting the value of the modal index of refraction of the

corresponding pixels in response to a control signal, so that the process applied to the incident radiation may be determined by the control signals applied to the control means.

31. A laser comprising a gain medium, pumping means for establishing an inversion in said gain medium and means for resonating optical radiation in said gain medium, in which:
said means for resonating radiation in said gain medium comprises at least one array of pixels comprising a supergrating, each pixel having a modal index of refraction selected from a set of index values, the array of pixels collectively processing the incident radiation, in which at least some of the array of pixels are connected to control means for controllably setting the value of the index of refraction of the corresponding pixels in response to a control signal, so that the process applied to the incident radiation may be determined by the control signals applied to the control means.

32. A laser according to claim 31, in which said supergrating resonates radiation in at least two wavelength ranges with a respective loss set by said control signals, thereby establishing a power spectrum determined by said control signals.

33. A laser according to claim 31, in which said supergrating is located outside said gain medium.

34. A laser according to claim 31, in which said supergrating is located inside said gain medium.

35. A laser according to claim 31, in which said supergrating is located inside said gain medium and said supergrating directs radiation of different wavelengths along different paths through said gain medium, thereby establishing a wavelength dependent length through said resonator.

36. A device for receiving optical radiation of at least two input wavelengths on at least one physically separate channels and combining it into a single output channel, comprising:
a least two input channels;
a one- or two- dimensional wavelength dependent supergrating adapted for deflecting radiation of different wavelengths and directing the deflected radiation toward said output channel.

37. A device according to claim 36, in which the one- or two- dimensional wavelength dependent supergrating deflects radiation away from the input directions of travel at angles that depend on the wavelength and focus that radiation into a waveguide for the output wavelength channel.

38. An optical device comprising at least one input port and at least one output port connected by asymmetric optical means having different attenuation in opposite directions, further comprising a supergrating coupling radiation within a pass band from the input port to the output port.

39. A device according to claim 38, in which the supergrating couples radiation traveling in a first

direction from a first waveguide to radiation traveling in the first direction in a second waveguide.

40. A device according to claim 38, in which the supergrating couples radiation traveling in a first direction in an input waveguide to radiation traveling in a second direction opposite to the first direction in an output waveguide.

41. A device according to claim 40, in which the input waveguide and the output waveguide are the same.

42. A device according to claim 40, in which the input waveguide and the output waveguide are physically separated.

43. An optical device comprising at least one input port and at least one output port connected by asymmetric optical means having different attenuation in opposite directions, further comprising a supergrating coupling radiation within a pass band from an input port to the next port in sequence.

44. An optical device comprising an input port and an output port disposed along an optical axis and connected by a supergrating coupling radiation within a pass band from the input port to the output port, further comprising a set of lateral pixels extending in two lateral directions that represent an analog profile that forms a design set of wave fronts.

45. An optical device according to claim 45, in which a set of pixels of said supergrating are controlled by controllable means, responsive to a set of control

signals, for altering the index of refraction value in corresponding pixels in said array.

46. A three-dimensional optical device comprising at least one waveguide in a first propagation layer of grating material for transporting input radiation from a first input port to output radiation exiting from a first output port, and a two dimensional supergrating in a modulation layer of grating material for coupling input radiation propagating from said first port out of said first propagation layer to at least one other propagation layer disposed along a third dimensional axis at a different location from said first propagation layer and having quantized pixels formed therein for processing said radiation; and

means for directing processed radiation toward said first output port.

47. A material comprising a layer of optically propagating material in a reference plane that transmits radiation in a wavelength range, the material being impressed with a pattern of index of refraction change such that propagation in the reference plane is suppressed, the pattern of index of refraction change being digitized from an analog index of refraction profile.

48. A material according to claim 47, in which the pattern of index of refraction change is modified to permit propagation of radiation in the wavelength range within a restricted area and in a restricted direction.

49. A material according to claim 47, that is disposed on a substrate of photo-electric material, whereby propagation of radiation that impinges on the photo-

electric material is facilitated compared with propagation of radiation that does not impinge on the photoelectric material.

50. A material according to claim 47, that is capable of laser action at a laser wavelength and has at least one localized area permitting propagation of radiation at the laser wavelength, whereby stimulated emission at the laser wavelength is confined to resonate within the localized area.

51. A material according to claim 47, that contains a waveguide that within which the pattern of index of refraction change is absent, such that radiation propagates within the waveguide, in which material the waveguide follows a curve having a radius of curvature less than a reference value.

52. A material according to claim 47, that contains two waveguides with a separation region therebetween, the separation region having the ability to propagate radiation within at least an attenuation length.

53. A material according to claim 52, in which the separation region has a pattern of index of refraction change that permits propagation with an attenuation length greater than the separation between the waveguides.

54. A material according to claim 47, in which the material supports a non-linear interaction between two input wavelengths that generates radiation of an output wavelength and the pattern of index of refraction change suppresses propagation of the two input wavelengths and the output wavelength; and

At least one waveguide is formed in the material for the propagation of the input and output wavelengths.

55. A method of forming a two dimensional supergrating in a modulation layer of grating material for converting input radiation propagating from an input source through a propagation layer of grating material to output radiation exiting from said grating on at least one output path comprising the steps of:

generating a two dimensional analog refractive index profile in the modulation layer that implements a transfer function relating electromagnetic fields characteristic of the input radiation and output radiation;

digitizing the analog refractive index profile to generate an array of pixels in the modulation layer having digitized refractive index values by using a two-dimensional technique that conserves Fourier information within one or more regions of the two-dimensional spatial-frequency representation of said two-dimensional analog refractive index profile; and

imposing the array of pixels representing the digitized refractive index profile on the modulation layer.

56. A method according to claim 55, further comprising the steps of selecting a two-dimensional sampling lattice of lattice pixels;

Setting a total device length and width;

In which the step of digitizing includes setting a value for the index of refraction in each lattice pixel of the total sampling lattice.

57. A method according to claim 55, in which the step of digitizing includes computing an intermediate sampled index profile wherein the value at each sample point of the sampled index profile is equal to the value for the index of refraction of the analog refractive index profile at a corresponding point on the sampling lattice.

58. A method according to claim 55, further comprising the steps of:

Converting the reflectance specifications of the transfer function to the Fourier Domain;

Specifying grating parameters in the Fourier Domain; and

Converting the grating parameters to the spatial domain, thereby determining the analog profile in the spatial domain.

59. A method according to claim 55, further comprising specifying phases of components of the analog refractive index profile such that the maximum refractive index value of the analog refractive index profile is minimized.

60. A method of forming an effective one dimensional supergrating in a modulation layer of grating material for converting input radiation propagating along an

axis from an input source through a propagation layer of grating material to output radiation exiting from said grating on said axis comprising the steps of:

generating a two dimensional analog refractive index profile in the modulation layer that implements a transfer function relating electromagnetic fields characteristic of the input radiation and output radiation;

digitizing the analog refractive index profile to generate an array of pixels in the modulation layer having digitized refractive index values by using a two-dimensional technique that maintains Fourier components within one or more regions of the two-dimensional spatial-frequency representation of said two-dimensional analog refractive index profile; and

imposing the array of pixels representing the digitized refractive index profile on a portion of the modulation layer extending laterally from the axis by a lateral distance.

61. A method of forming a three-dimensional supergrating in a modulation volume of grating material for converting input radiation propagating from an input source through the grating material to output radiation exiting from said grating on at least one output path comprising the steps of:

generating a three-dimensional analog refractive index profile in the modulation volume that implements a transfer function relating electromagnetic fields characteristic of the input radiation and output radiation;

digitizing the analog refractive index profile to generate an array of pixels in the modulation layer having digitized refractive index values by using a three-dimensional technique that conserves Fourier information within one or more regions of the three-dimensional spatial-frequency representation of said two-dimensional analog refractive index profile; and

imposing the array of pixels representing the digitized refractive index profile on the modulation layer.

62. A method of forming a one or two or three dimensional supergrating in a modulation layer of grating material for converting input radiation propagating from an input source through a propagation layer of grating material to output radiation exiting from said grating on at least one output path comprising the steps of:

Generating a one dimensional analog refractive index profile P in the modulation layer that implements a transfer function relating electromagnetic fields characteristic of the input radiation and output radiation;

generating a filter function H that selects the spatial-frequency ranges in which spectral information is conserved and assigns weights thereto;

solving the optimization problem represented by

$$\min_{X,V} C = \min_{X,V}\left[\sum\left|H(P-X)\right|^{L} + \sum_{i} V_i\left(X_i - n_{low}\right)\left(X_i - n_{high}\right)\right],$$

where X is a vector containing the Binary Supergrating's refractive index values, V is a vector of Lagrange multipliers, L determines the type of optimization, and n_{low} and n_{high} are the Binary Supergrating's low and high refractive index values, respectively; thereby computing a Binary Supergrating refractive index profile, X, in the modulation layer that converts the input radiation to the output radiation; and

imposing the array of pixels representing the digitized refractive index profile on the modulation layer, whereby the input radiation is converted to the outpt radiation.